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AFAL-TR-75-12

REAL-TIME DRY SILVER FILM DEVELOPMENT USING CO_2 LASER IRRADIATION

AIR FORCE AVIONICS LABORATORY

SYSTEMS RESEARCH LABORATORIES

TECHNICAL REPORT AFAL-TR-75-12

June 1975

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Air Force Avionics Laboratory
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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The report has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

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1. ~~REPORT NUMBER~~ (14) AFAL-TR-75-12 ✓	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) REAL-TIME DRY SILVER FILM DEVELOPMENT USING CO_2 LASER IRRADIATION.		5. TYPE OF REPORT & PERIOD COVERED (9) Final Report. Jul[redacted]-Sep[redacted]74
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) William E. Boney, Joseph E. Brandelik, R. F. Paulson, Arnold		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS AF Avionics Lab., W-P AFB, OH 45433 and Systems Research Lab., 2800 Indian Ripple Rd. Dayton, OH 45440 ✓		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project 2001 ~~WU 15~~ ~~Task 01~~ (16) AF-2001
11. CONTROLLING OFFICE NAME AND ADDRESS Air-Force Avionics Laboratory Wright-Patterson Air Force Base, Ohio 45433		12. REPORT DATE (11) June [redacted]75 (17) 200101
		13. NUMBER OF PAGES 31 (12) 39p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. Government agencies only; test and evaluation results reported; December 1974. Other requests for this document must be referred to the Air Force Avionics Laboratory (AFAL/TEO), Wright-Patterson AFB, Ohio 45433.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dry Silver Film Development
Carbon Dioxide Laser
Film Sensitization
Optical Homogeneity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the preliminary results of a feasibility demonstration of real-time (less than 1 sec) development of 3M 7969 dry silver film utilizing a CO_2 laser under nonscanning, static area conditions. The standard thermal development procedure for this film requires 15 seconds of exposure at 250°F. It was surmised that the use of a CO_2 laser beam as a heat source would result in a substantial reduction in the development time. Initial estimates indicate

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that a 10-100 watt diffraction limited cw laser beam operating at 10.6 microns will do the job. Linear extrapolation of experimental results indicates that a single mode (TEM_{00}), single line P (20), CO_2 laser of approximately 16 watts average power will satisfy the real-time development requirement for line scan recorders with a writing rate of 0.25 MHz on film with a resolution of 2000 lines per inch. Spectroscopic examination of the film coating indicated that a (00°1) to (10°0)R(28) CO_2 laser would reduce the laser requirement to 5 watts.

FOREWORD

This report was prepared by Captain William E. Boney III, Capt, USAF, and Dr. Ronald F. Paulson of the Electro-Optical Sources Group (TEO), Air Force Avionics Laboratory, in conjunction with Mr. Joseph E. Brandelik of Systems Research Laboratories.

The authors would like to express their sincere appreciation to Mr. Schoonover (RSP) who suggested this problem as well as to Mr. Lewis (RSP) and Mr. Zonar (RSP) both of whom went out of their way to furnish film samples along with valuable background information on film processing.

The work began in July 1974 and was completed in September of 1974. This effort is documented under Project 2001, "Laser Technology;" Task 01, Work Unit 15, "Gaseous Lasers."

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SECTION I

INTRODUCTION

1. BACKGROUND DISCUSSIONS AND STATE OF THE ART

Dry silver film processing is basically a two-step procedure-sensitization (recording) followed by development. In this report a new technique which can accomplish the two goals simultaneously employing two lasers, i.e., one to record and one to develop the film, is proposed. This has the advantage of enhanced speed capability both in start time and processing time, as explained later on in this document.

Recording with focused laser beams is a well-established technique used in film processing and is relied on because of enhanced flux density capability over conventional recording techniques (Reference 1). In all of these systems the TEM_{00} laser mode is used to obtain nearly diffraction limited performance, vis-a-vis the optical system. The laser wavelengths typically used for recording are in the visible region of the spectrum because of the inherent film sensitization characteristics. Generally the film is developed in an auxiliary unit by way of a process which requires a specific temperature for a given amount of time (References 2 and 3).

In a time period encompassing the last six years, the sensitivity of dry silver films have shown a substantial quality improvement. In 1968, 3M 370 film (Reference 4) was considered the best in film sensitization and development work. Since that time, numerous improvements in quality have resulted in 3M7969 film. In this report the improved version has been utilized for the majority of the tests and analyses, since it is representative of films presently being used by the Air Force.

In considering dry silver film development by lasers, the following must be taken into account:

A. The material must absorb energy at the wavelength in question.

B. The laser must provide the required energy to develop the film.

C. The optical system employed must be capable of projecting a uniform energy density beam.

D. Power density of the developing laser beam must be limited to avoid destruction.

In these experiments spectroscopic measurements were used to determine the wavelength of the radiation absorbed by the film. Static area (nonscanning) experiments were accomplished to determine the energy flux density required to develop the film, as well as to establish the upper limit in power density which would avoid destruction of the film. Analytic extrapolation of the results of the static tests to scanning conditions were performed.

2. EXPERIMENTAL APPROACH

The approach delineated in this report on latent image development entails the utilization of a focused CO_2 laser beam to develop 3M7969, UV sensitive dry silver film. The CO_2 laser would supply the necessary thermal energy to raise the temperature of the film coating, thus resulting in a fully developed dry silver film product.

These initial tests were intended to demonstrate the feasibility of developing dry silver film at the same rate of area exposure as occurs when it is sensitized in system applications (i.e., real time). Many different potential systems can be envisioned which utilize various scanning patterns and laser spot sizes to develop the films for a large range of rates. Rather than choose a specific scanning system for this effort we conducted static area experiments. That is, the film was fully sensitized (i.e., D_{max} when fully developed) using an UV source. A given area of the sensitized film was then exposed to CO_2 laser radiation for a given time using time shuttering of the laser beam. The extent of the development was determined by comparing the density of the laser developed film with D_{max}.

These experiments gave values of energy density and times to develop the film to D_{max} without destroying the film. The results were linearly extrapolated in area to determine the laser power requirement for the scanning case.

3. POTENTIAL AIR FORCE APPLICATIONS

Air Force applications of line-scan recording include real-time recording and display for active imaging reconnaissance and forward-looking infrared sensors. The rapid development approach delineated in this technical report could also enhance navigation of RPV's by optical correlation map matching techniques.

One USAF system which employs laser line scanning is a mini-RPV recon system. In that system, the light beam from a gallium arsenide laser is intensity modulated by the recording signal. The laser beam is then expanded to fill the imaging lens and focused to a diffraction-limited spot. A polygonal rotating mirror located within the focus of the imaging lens deflects the modulated spot at a rate of 850 cm/sec (330 in/sec) in the image plane. Silver halide film, 70 mm wide, is transported past the scanning laser beam and is exposed, resulting in a transverse trace similiar in format to television tape recording. A CO_2 laser system for real-time development of the film can be envisioned for this application.

The CO_2 laser development process can also be used for conventional laboratory or field Air Force applications now utilizing dry silver film.

SECTION II

EXPERIMENTAL APPARATUS AND TECHNIQUE

The experimental apparatus can be broken into four basic components: (1.) Laser, (2.) Optics, (3.) Film, and (4.) Monitors. In this section each component will be discussed separately to furnish the necessary background and description so that the system as a whole can be brought into perspective by the discussion in Section III.

1. LASER

The film development tests were performed by using a cw CO_2 laser operating typically on the single P(20) transition (10.6 microns). The laser was a longitudinal-discharge slow-flowing system with an amplitude stability of $\pm 5\%$. The laser energy was coupled out by a 15% partially transmissive mirror. The totally reflecting mirror of the laser optical resonator was mounted on a piezoelectric element to allow wavelength selection (Reference 5). The use of a Brewster angle NaCl window at the output end of the discharge tube resulted in a plane-polarized output. The optics, including an internal aperture, were adjusted to allow the laser to operate at all times in the TEM_{00} transverse mode. The beam size exciting the laser cavity was 6 mm.

The output power of the laser, typically 1 to 5 watts, was controlled by varying the current, voltage, and pressure of the discharge plasma. A gas premix was used, which consisted by volume of 63.2% He, 25.2% N_2, and 11.6% CO_2. Gas flow was achieved by a 35 l/min forepump. The discharge tube pressure was nominally 15 torr. Further information on CO_2 laser parameters can be obtained from AFAL-TR-74-110 (Reference 6).

2. OPTICS

A 2-inch diameter 4F number Irtran IV lens was utilized to focus the CO_2 laser radiation so that the film could be exposed to a high flux density. The flux density was varied by changing the distance between the lens and the film. The emulsion or coating side of the film faced the

CO_2 laser at a location between the lens and its focal point for most of the experimental work. However, in experiments requiring larger surface area exposure, the distance between the lens and film exceeded the focal length of the lens.

The total energy coupled into the film was controlled by an iris shutter/timer with an operating range of 1/500 sec to 1 sec.

Focusing optics were used because they allowed the power to approach the density likely to be encountered in an operational line-scan recording system.

With all materials there are anomalies (outgassing, plasma formation, ablation) which occur when the laser power density is very high. The optical arrangement used in this experiment did not lay to rest the question of possible experimental aberrations encountered by the use of a 20 μm spot size, dwell times as short as 1.52×10^{-7} sec, and power densities of 33 MW/cm^2, which would apparently be required for a drone-laser line-scan recorder system. In like manner, a mini-RPV reconnaissance system would apparently require a dwell time of 1.52×10^{-6} sec on a 3×10^{-6} cm^2 spot with a CO_2 laser power density of 3.3 MW/cm^2. Laser power densities of these magnitudes are in the nonlinear response range of most materials and an experimental spot-scanning system will be required to determine anomalous behavior.

3. FILM

Dry silver film was developed originally by the 3M Co. for electro-beam recording (Reference 7). The 3M dry silver films typically require less than 200 ergs/cm^2 (Reference 8) for film sensitization. These are also typical values of sensitization energy density in the visible or UV region of the spectrum for latent image formation making 3M dry silver film ideally suited for laser recorders. This type of dry silver film (3M type 7969) is a negative-acting continuous-tone grade of dry silver film on a 3 mil polyester base. The dry silver film has the following parameters (Reference 9):

Contrast Range Gamma	D max Exceeds	D min Less than	High Contrast Resolution Exceeds (cy/mm)
1.8 to 2.8	2.0	0.15	400

The 3M dry silver film, type 7969, contains microencapsulated globs of "developer-fixer." When subjected to a temperature of 240-260°F it takes 15 seconds or more to develop, an event which is controlled by the rupturing and diffusion of the microencapsulate material. The exact chemical composition of the 3M film is company proprietary.

4. MONITORS

The experimental method employed to monitor the CO_2 laser power and wavelength as well as the method used to monitor the photographic film density will be explained in this section.

Approximately one minute before and after each CO_2 laser irradiation of the film, the cw laser power was measured with a Coherent Radiation Model 123 power meter. The power meter was replaced with an Optical Engineering CO_2 Spectrum Analyzer after each power measurement, in order to observe the value of the laser transition. A single P transition was maintained for periods of up to 10 minutes without optical adjustments. Fluorescent plates were used to ensure that the laser was still operating in the TEM_{00} mode. The temporal amplitude stability was $\pm 5\%$ from 5Hz to 1MHz and was checked periodically to ensure compliance. It did not vary from this value on a day-to-day operational basis. The amplitude stability will have important consequences in the final scanning system where beam uniformity or lack thereof will be reflected in the fully developed film (picture clarity).

A helium/neon laser was employed to monitor the transmission of the film. In most of the experiments the He-Ne and CO_2 laser beams were coincident on the film. The density (D) of the area of the film exposed to the CO_2 laser radiation was monitored by measuring the helium neon laser power after it passed through the film and impinged on an HEP 312 phototransistor. For this experiment the effects of a 1 mw He-Ne laser in developing the latent image of the film was assumed to be negligible, based on the measured negligible effect on film development due to the NeHe laser alone.

Figure 1 is a schematic of the total experimental setup used to determine the energy required to develop film when irradiated by a CO_2 laser under nonscanning conditions.

The resultant current variation in the photo transistor was monitored as a voltage change across a 1000 ohm resistor and readout on a digital voltmeter. These readings were compared with the voltage readings obtained from known film standards (controls) of various densities. These standards had been prepared from 7969 film with 0.15 density steps and developed in the standard thermal development manner. The density was also checked by visual observation and comparison. Thus, the log I density readings were determined analytically by the voltage readings and by visual comparison.

The static area of film exposed was calculated and controlled by adjusting the distance from the IRTRAN lens to the film. The laser spot size on the lens was approximately 7 mm and the focal length was 8 inches. The magnitude of the area was also determined graphically. The graphical method was used to compare the diameter of a circle of equivalent area to the approximately circular area with an irregular boundary developed by the laser.

Figure 4 in Section III shows the complete experimental setup for the exposure and real-time development of the subject film.

In experiments where real-time characteristics were measured, the time the CO_2 laser irradiated the film was monitored by a second HEP 312 phototransistor with a second helium neon beam passing through the timed iris shutter. The iris time and photo "density" were displayed on a Tektronix 555 oscilloscope.

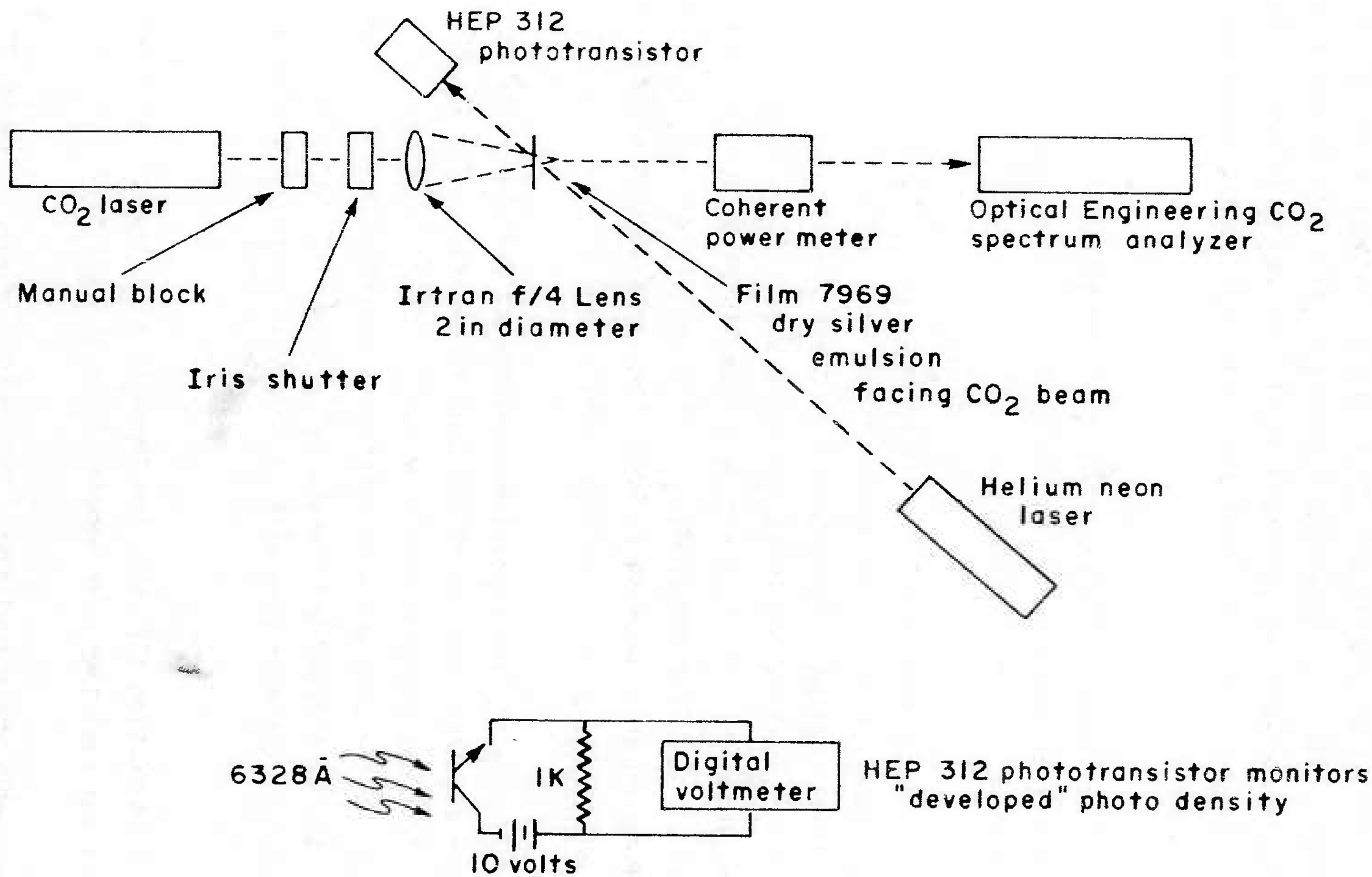

Figure 1. Experimental Setup Used in Determining CO_2 Energy Requirements for Film "Development"

SECTION III

EXPERIMENTAL RESULTS

A series of tests were run with different CO_2 laser irradiation times, energy densities, power densities, and film development areas (Table 1).

It was found that the energy range between 5 joules/cm^2 (i.e., essentially not developing the film) and 20 joules/cm^2 (i.e., destruction of the film) had to be tested to determine the degree of development with variation in energy density.

Within this range of energy densities, the CO_2 laser beam [P(20)] used in these static experiments was TEM_{00} and hence the preponderence of the energy was between the $1/e^2$ intensity points. In other words, there was a very high power density at the center and low power density at the circumference. It was observed, under high intensity operation, that decomposition (vaporization) occurred in the very center and a steady transition to almost invisible and undetectable effects at the circumference of the exposure. In the final scanning system corrections for this phenomena will have to be made with beam-correcting optics.

Oscilloscope traces of the HEP 312 phototransistor output taken during the experiment revealed the following:

(a) When the CO_2 laser (10.6μ) and the He-Ne (6328 Å) were not coincident on the same region an apparent "temporary" density increase occurred which was transitory in nature and disappeared at the end of 15 seconds. We presently attribute this phenomena to thermal distortion of the polymer, causing the film surface to change orientation, but not to variation in density due to film development (Figure 6).

(b) Abnormally prolonged film development times are attributed to: (1) nonuniform CO_2 laser beam characteristics and (2) the condition when He-Ne monitoring beam does not cover the entire area exposed to CO_2 laser radiation. As the area being exposed to CO_2 radiation was decreased by an aperture, resulting in a more uniform distribution, the transitory density characteristic disappeared (Figure 5).

(c) In general, the oscilloscope readout indicated that the film was developed by the P(20) CO_2 laser transition in approximately 1/5 second at 20 joules/cm^2 (Figure 7).

The experiment was modified by placing the film beyond the focal point of the IRTRAN lens. It was found that the use of a 1-watt laser and exposures of 3-7 seconds for an area of 1/8- to 1/4-inch diameter gave the following results:

(1) Generally, between 5 and 20 joules/cm^2, for a given area, are required to develop the film with a CO_2 laser.

(2) The CO_2 laser developed density was $D \geq 2$ for D_{max} exposure, $D \approx 0$ for D_{min} exposure, and D=0 for the base material with the coating removed (The coating was removed from the base by means of an acetone solvent).

(3) When the film was over developed (not destroyed) it turned brown in color. When too much (destruction limits of the film) radiation is used the film melts or vaporizes rather than char (this was observed for the conditions mentioned in (2) and (3)).

(4) Beam quality or laser power (energy) distribution must be uniform. The lack of a uniform beam will cause selective spatial over-heating. The parameter of uniformity is critical since the energy range from proper development to overdevelopment for good photography varies by less than 10%.

Table 1 does not include data where partial destruction of the film occurred. Therefore, much of the higher density readings are not included. The film had been pre-exposed to D_{max} level by a fluorescent lamp; hence, the objective of using the CO_2 laser radiation was to produce a maximum developed-film density.

TABLE 1

EXPERIMENTAL DATA ON CO_2 LASER ENERGY REQUIREMENTS for FILM "DEVELOPMENT"

Beam Area (cm^2)	C. W. Laser (watts)	Exposure (sec)	Energy (Joules)	Energy Density (j/cm^2)	Optical Δ (density)
0.06	0.5	1/2	0.25	4	0.0
		1	0.5	8	0.1
		2	1.0	17	0.3
		3	1.5	25	0.45
		4	2.0	33	destruct
	3.0	1/8	0.4	7	0.0
		1/5	0.6	10	0.15
		1/4	0.75	12	0.15
		1/3	1.0	17	0.3
		1/2	1.5	25	0.45
		1	3.0	50	destruct
0.02	1.5	1/8	0.2	10	0.0
		1/5	0.3	15	0.15
		1/4	0.4	20	0.6
		1/3	0.5	25	1.0
		1/2	0.75	37	destruct
	3.0	1/10	0.3	15	0.15
		1/8	0.4	20	0.6
		1/5	0.6	30	1.5
		1/4	0.75	37	destruct
0.005	0.5	1/10	0.05	10	0.15
		1/8	0.06	12	0.45
		1/5	0.1	20	1.0
		1/4	0.13	26	destruct
	1.5	1/30	0.05	10	0.0
		1/10	0.15	30	destruct
	3.0	1/30	0.1	20	0.6
		1/10	0.3	60	destruct

The optical density readings were obtained by the combination of visual observation and digital voltmeter readout, compared with a calibration standard (control) with step density variation.

Figure 2 is a plot of the experimental data. Developed density versus CO_2 energy density for different development areas is plotted. The optics utilized to focus the CO_2 laser radiation on the film produced an aberrated, nonuniform beam. The difference between the 0.06 cm^2 area's slope and other areas slope is attributed to the film heating characteristics and the nonuniformity of the beam. The curves in Figure 2 allow an estimation of the CO_2 laser energy density required for any specified D_{max} that does not exceed film destruction limits. The areas indicated are to be considered estimates and can be larger by a factor of two than those listed, due to the nonuniformity of the CO_2 beam after focusing with the IRTRAN lens.

Figure 3 is a plot of the CO_2 energy density versus the square root of the "developed" area for different development densities. The plot indicates that for very small developed areas, film development should occur at energy densities in the range of 10 to 16 joules/cm^2. The method of estimating the developed areas by visual comparison is believed to have indicated an area which was too small by a factor of two. Later experiments with an improved optical beam and diverging optics, rather than the converging optics for which the data of Figure 2 was taken, tend to confirm the 5-to-8 joule/cm^2 energy for development.

Figure 4 illustrates the experimental setup used to display the development time characteristics of a small film area. Phototransistor T1 allows for the monitoring of the CO_2 laser irradiation time. Phototransistor T2 allows for the monitoring of the film density.

Figure 5 illustrates "large" area experimental results of the transitory development of the film. Deflection of the monitor beam is a transient behavior attributed to the film's polymer base reorientation due to thermal effects. Reorientation is a common phenomena of heated polymers (Reference 10).

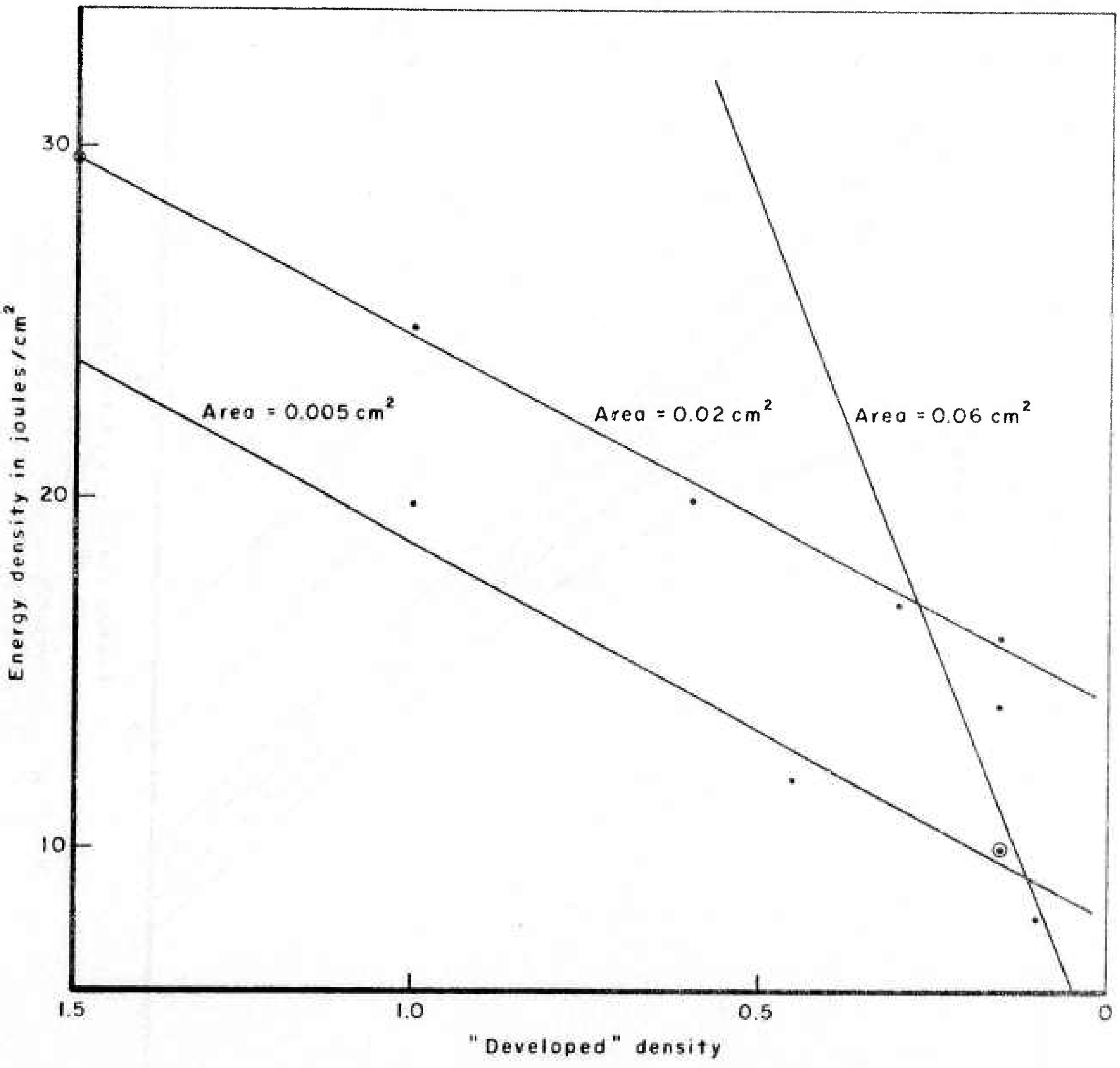

Figure 2. Experimental Data Showing Developed Film Density Versus CO_2 Laser Energy Density with Constant Area

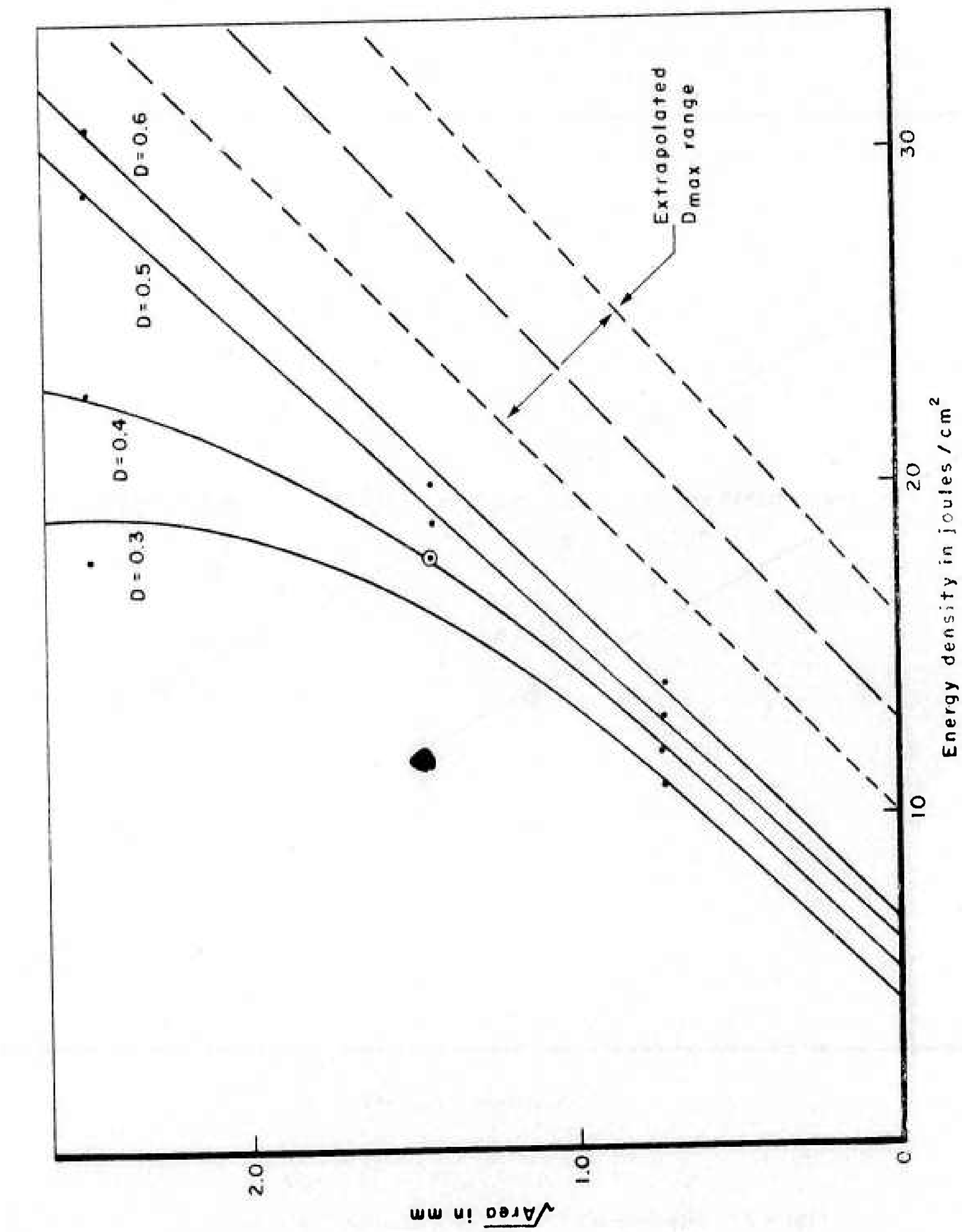

Figure 3. Experimental Data Showing Developed Film Area Versus CO_2 Laser Energy Density with Constant Density

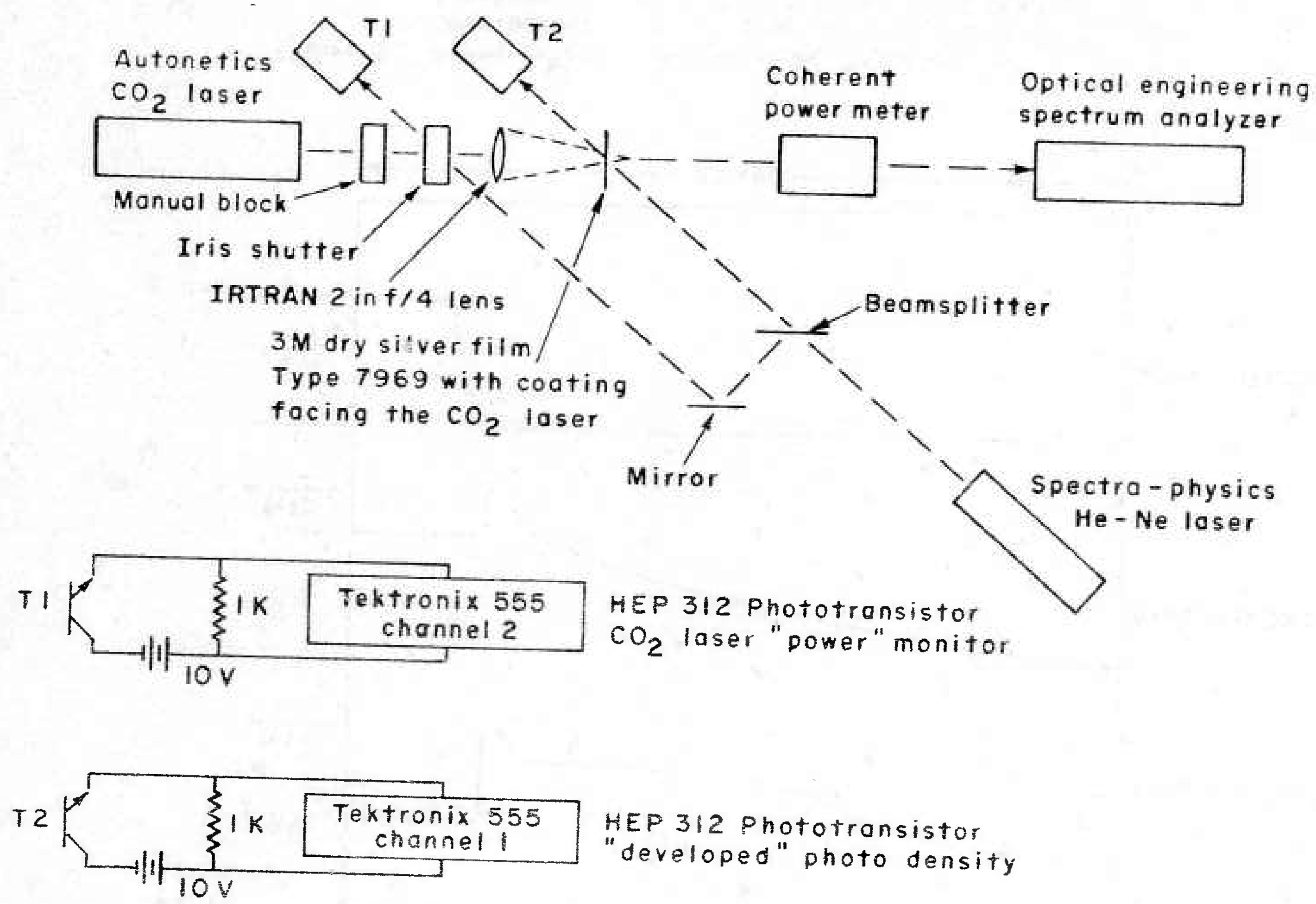

Figure 4. Experimental Setup for Determining Film Development Time and CO_2 Laser Illumination Time on Film

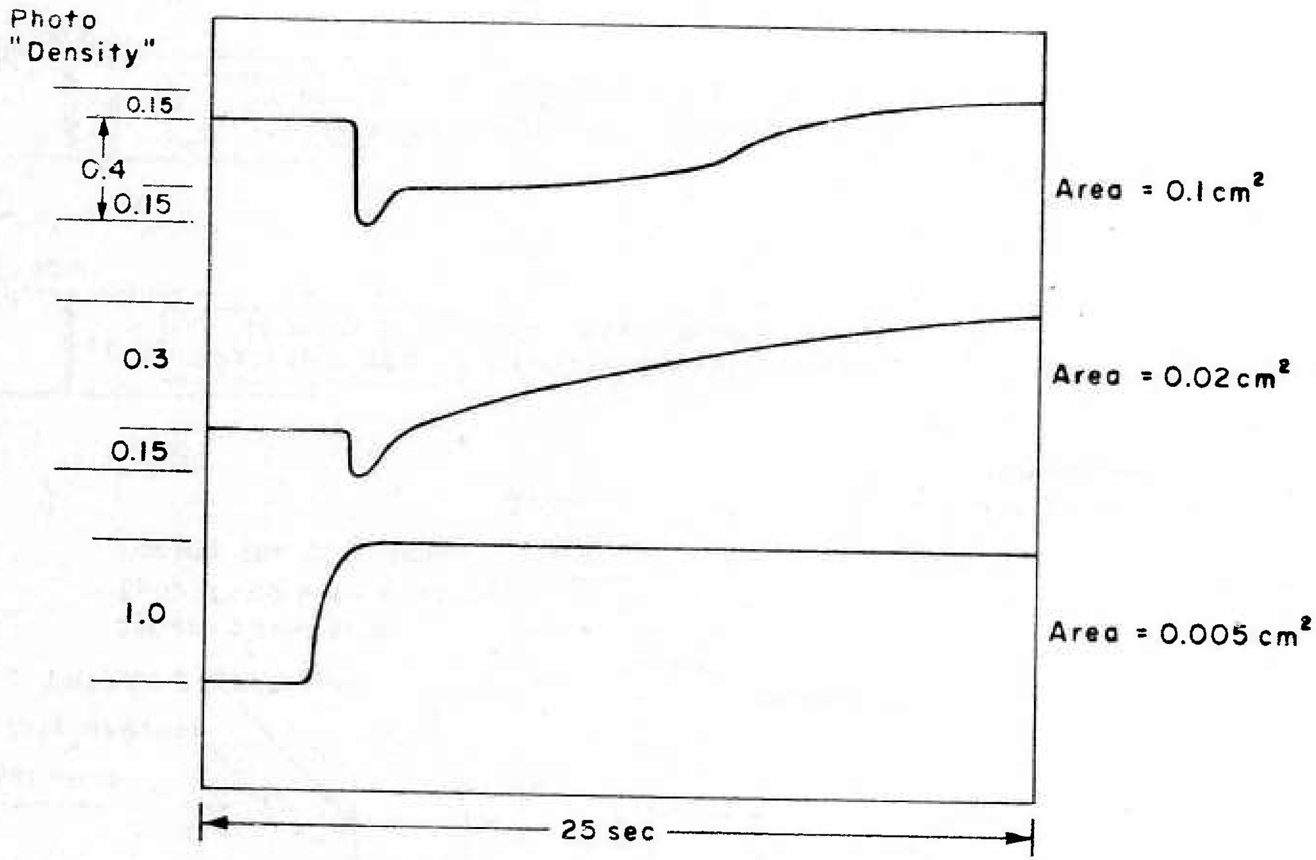

Figure 5. Representative Oscilloscope Trace of Film Development as a Function of Time with Film Development Areas of 0.1, 0.02, and 0.005 cm^2

Figure 6 is an oscilloscope trace indicating the anomalous "transitory" density variation of the film. Such reorientation of polymer films occurs in other films such as polyethylene (Reference 10).

Figure 7 illustrates the rapid development of pre-exposed (to D_{max}) film when subjected to CO_2 laser irradiation. Observe from this scope trace that the film "develops" in $\approx$1 second.

Figure 8 is a representative oscilloscope trace of the real-time (less than 1/4 sec) development characteristics of the film when exposed to CO_2 laser irradiation. The oscilloscope traces displayed linear rather than log values; hence, 10^D, not D, is the scale, so that the 0.15 to 0.75 density is a nonlinear scale. The 0.15 and 0.75 are comparative readings from calibration standards. A reduction in CO_2 beam spot size reduced the transitory density variation, due to base reorientation. This reduction in reorientation of the base material is attributed to improved laser beam quality relative to the density monitoring system.

Figure 9 indicates the transmission of 3M type 7969 film. The spectral trace was taken on a Cary Model 14 spectrometer. An UV wavelength cutoff at $\approx$ 315 nm for undeveloped film, exposed to D_{max} level, is indicated by this spectral trace.

Figure 10 indicates the 2.5 to 4.0 micron transmission of 3M 7969 dry silver film. The spectral trace was taken on a Beckman IR9 spectrometer. The undeveloped film and the base material (prepared by removal of the coating with acetone) had the same transmission characteristics within 2% and are thus shown as a single graph. Film thermally developed in a 3M developer with densities of 0.44, 1.0, and 2.2 (D_{max}) had transmission curves within 3% transmission of each other and thus are illustrated as a single graph.

Figure 11 indicates the 9-to-14-micron-transmission properties of 3M 7969 dry silver film. The spectral trace was obtained using a Beckman IR9 spectrometer. In the 9-to-14-micron-spectral region, the following

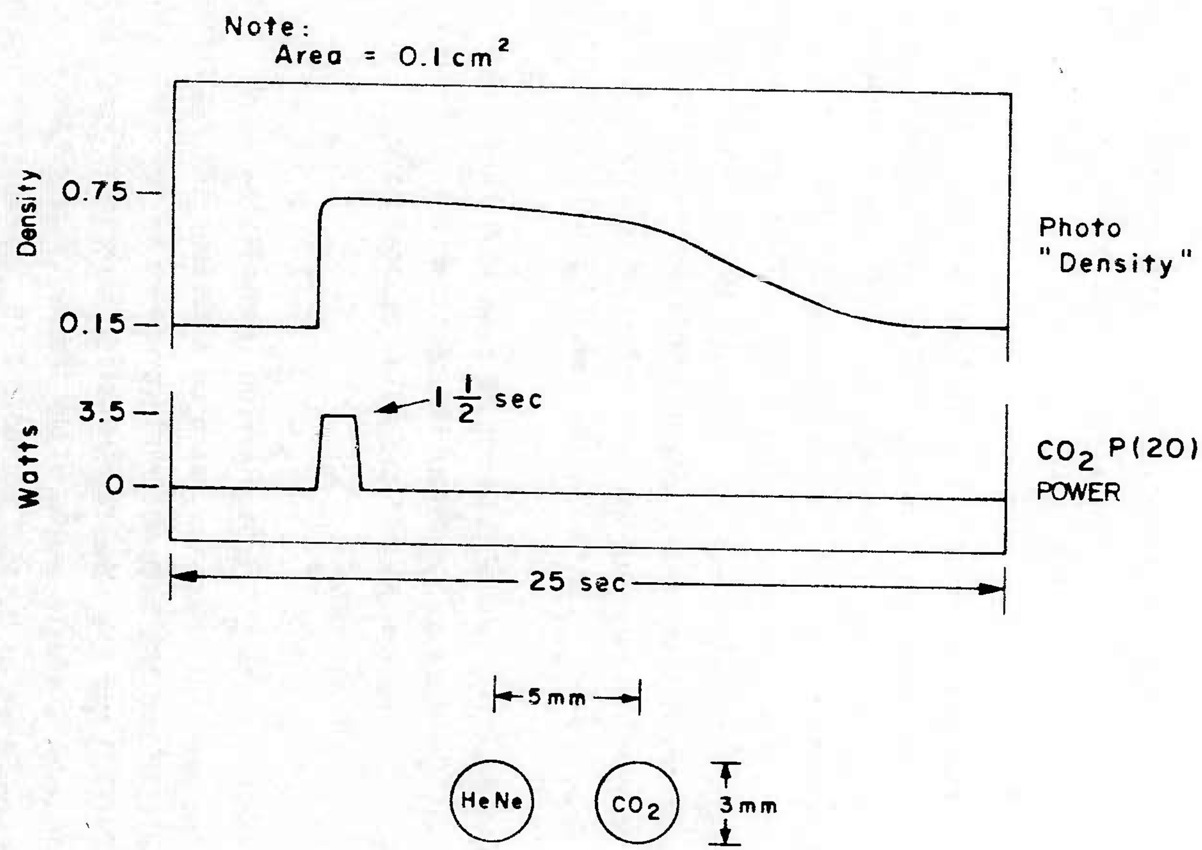

Figure 6. Representative Oscilloscope Trace of "Temporary" Apparent Film Development Indicating Film Base Reorientation Phenomenon

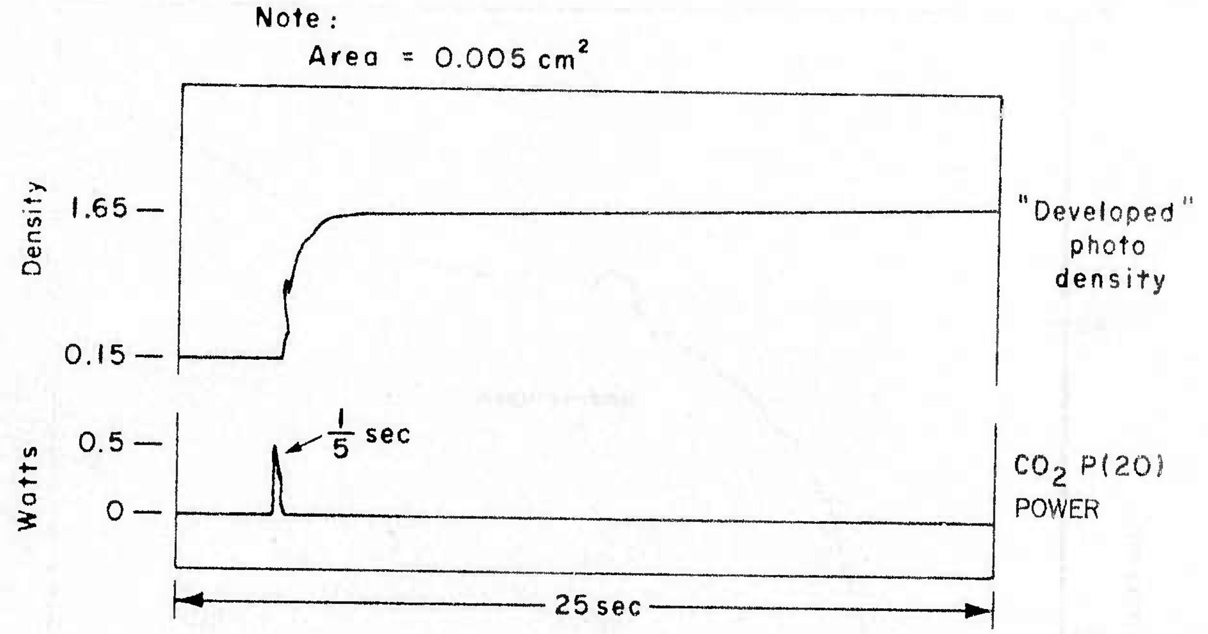

Figure 7. Representative Oscilloscope Trace of Film Development Time Using CO_2 Laser Irradiation and 0.005 cm^2 Film Development Area

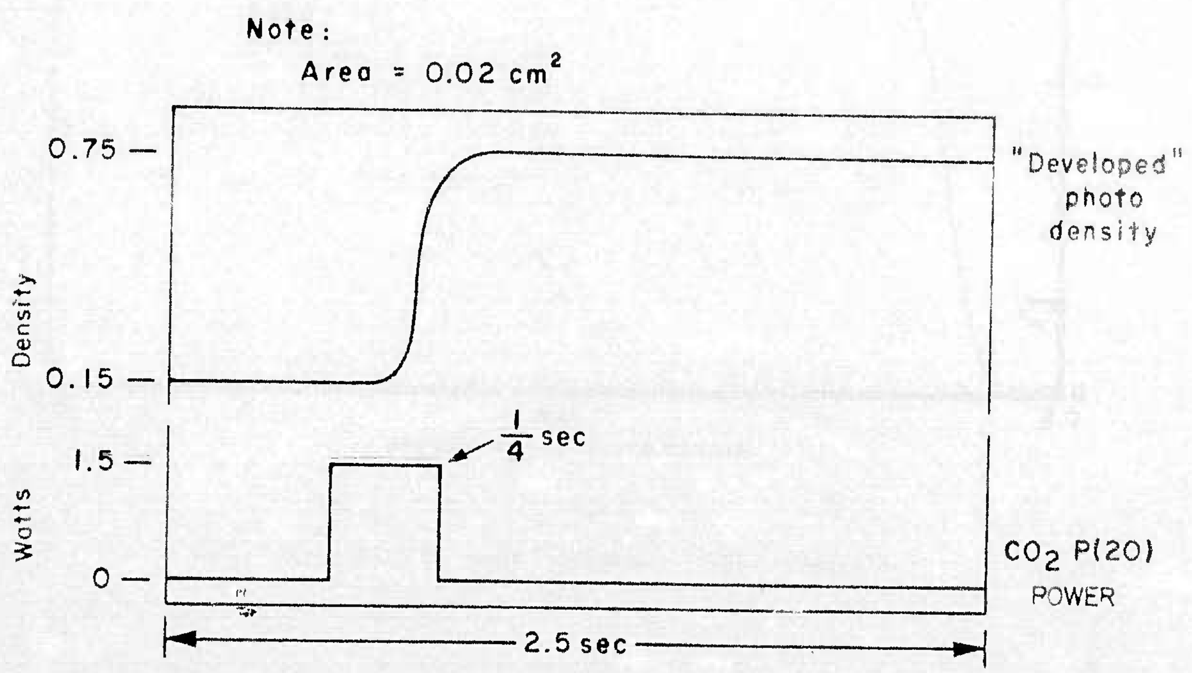

Figure 8. Representative Oscilloscope Trace of Film Development Time Using CO_2 Laser Irradiation and 0.02 cm^2 Film Development Area.

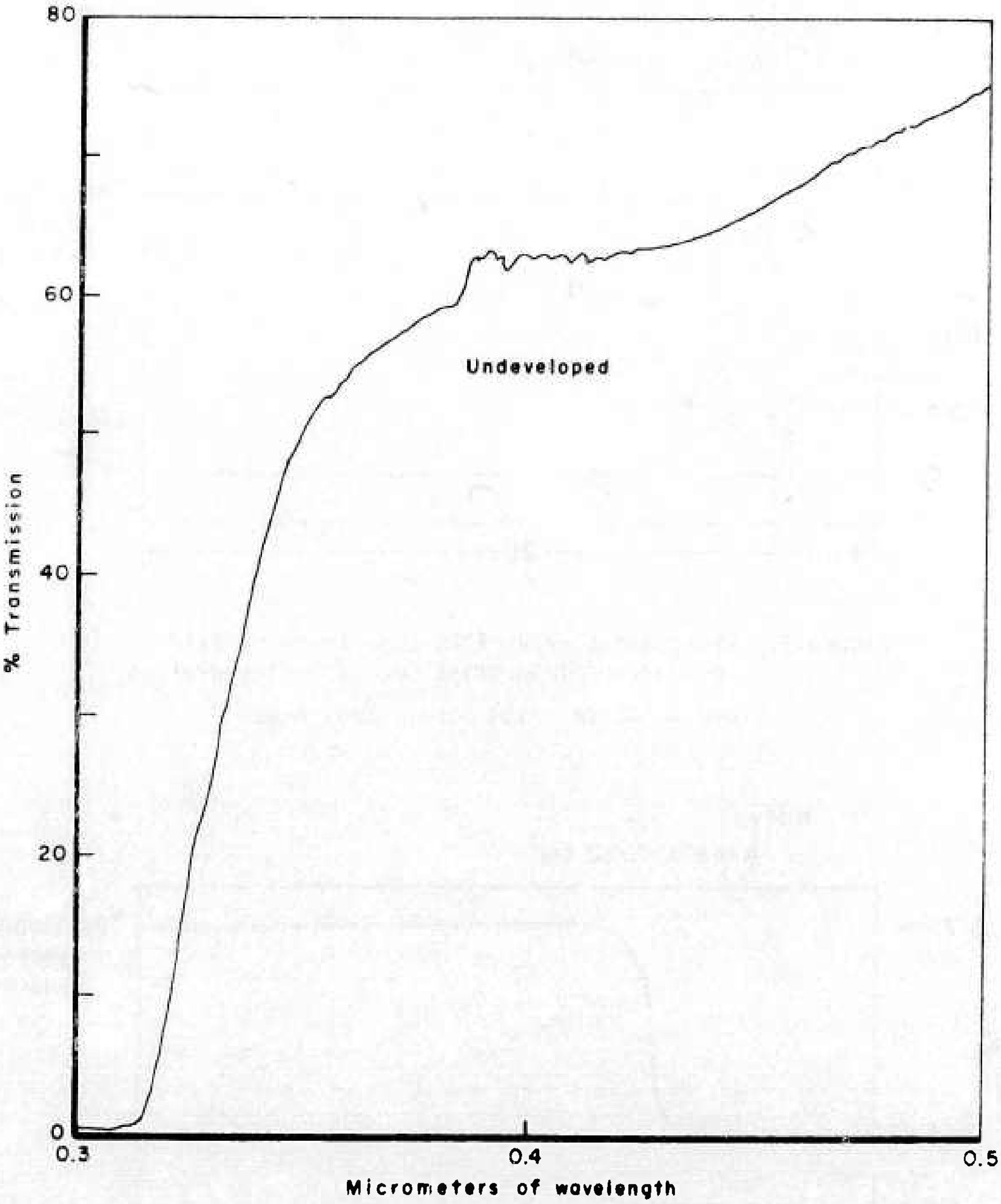

Figure 9. "UV" Transmission Curve of 7969 Film

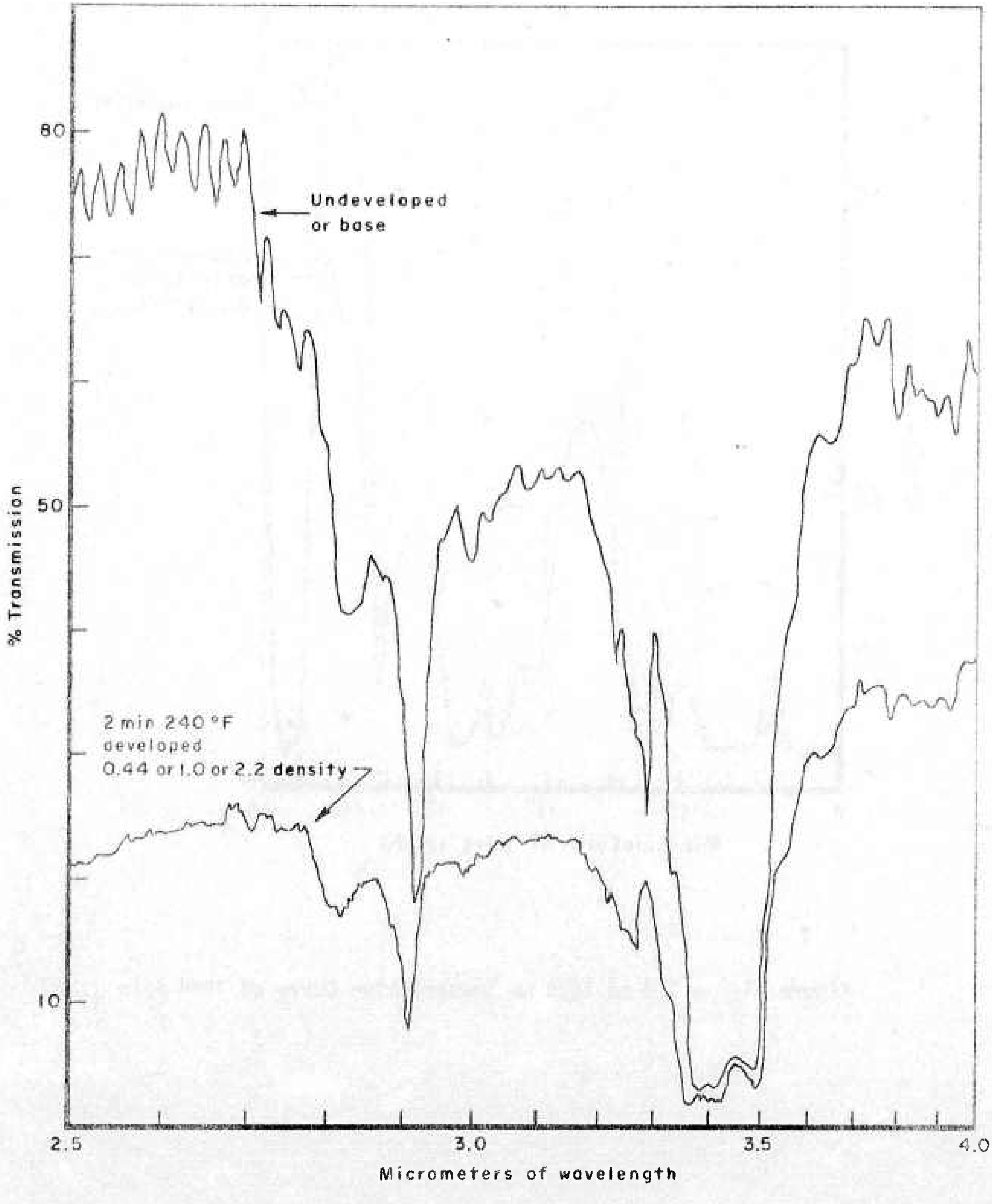

Figure 10. A 2.5 to 4.0 μm Transmission Curve of 7969 Film

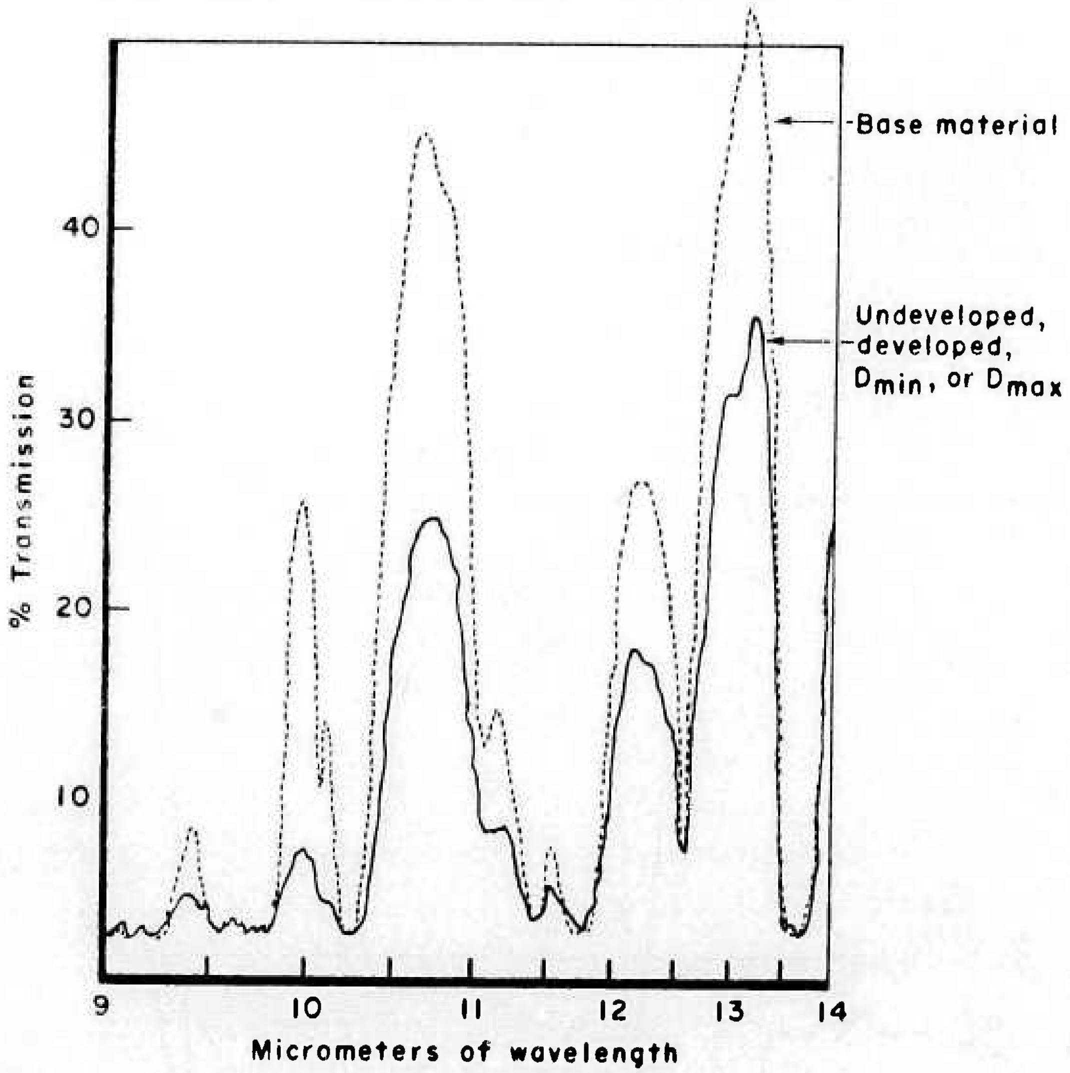

Figure 11. A 9.0 to 14.0 μm Transmission Curve of 7969 Film

film conditions had the same transmission curve within 3% and, thus, only one graph is provided: (1) film developed by a 3M thermal processor with D_{max} pre-exposure, (2) film developed by a 3M thermal processor with D_{min} pre-exposure, (3) undeveloped film pre-exposed to D_{max}, and (4) undeveloped film pre-exposed to D_{min}. The base material's transmission was taken after stripping the coating from the film with acetone. At 10.6 microns, the film absorbs ~75% of the energy with the base absorbing 50% and the coating absorbing 25%.

Figure 12a is a transmission curve of the coating only. The material for this transmission curve was obtained by (1) removal of the coating from the film by acetone, (2) vacuum evaporating the acetone, and (3) mounting the resulting thick film, approximately 1/2 mm, for spectroscopic investigation on a Beckman IR-9 spectrometer.

Note that 10.0 to 10.2 μ or 8.6 to 9.2 μ would be optimum in the 8 to 13 micrometer region for film development. The use of these wavelengths should reduce laser power requirements on the "development laser" by as much as a factor of 4, as well as reduce base reorientation problems.

The transmission curve indicates that 10.6 μm is <u>not</u> optimum for film development. But from Figure 12b we observe that isotopic CO_2 lasers are available for the more desirable wavelength ranges (Reference 11).

Figure 13 is the transmission of the coating material. The coating was prepared in a manner similar to that of Figure 12a.

Figure 13a is the spectral transmission of the coating from 6.6 to 10.5 μm and 13b from 3 to 4 μm. From this set of IR-9 transmission curves observe that there are presently no high power lasers available for optimal absorption except the CO_2 laser running on R transitions.

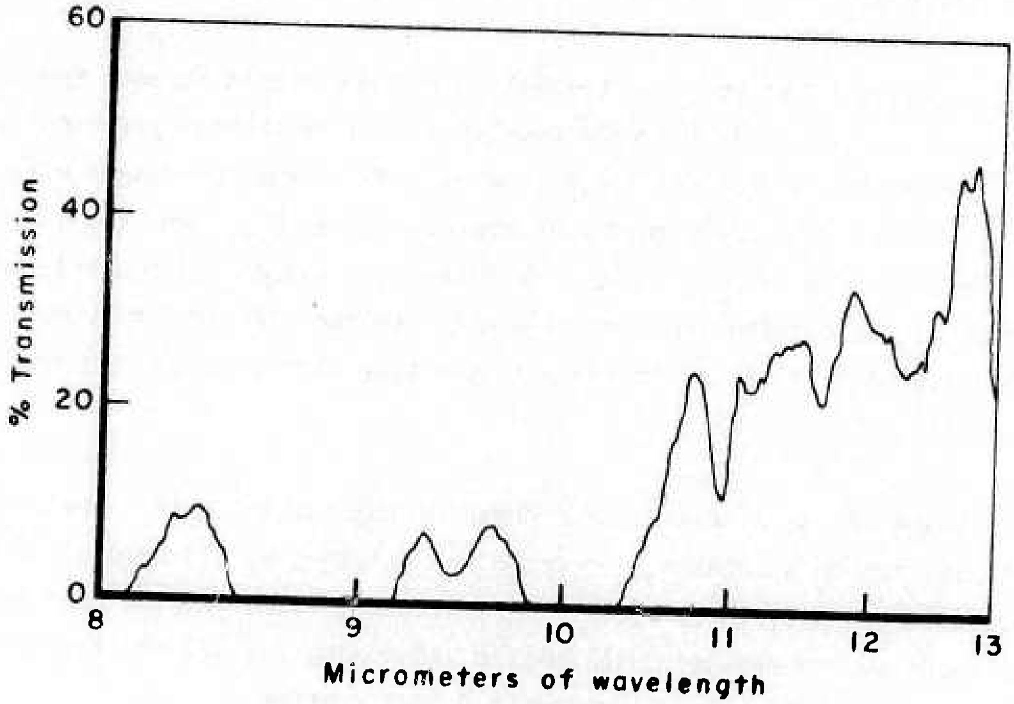

Figure 12a. An 8.0 to 13.0 μm Transmission Curve of 7969 Film Coating

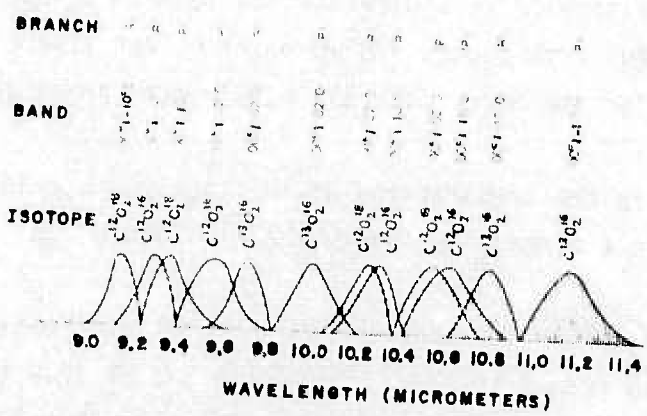

Figure 12b. Relative Laser Output Powers Available for Different Isotopes of CO_2

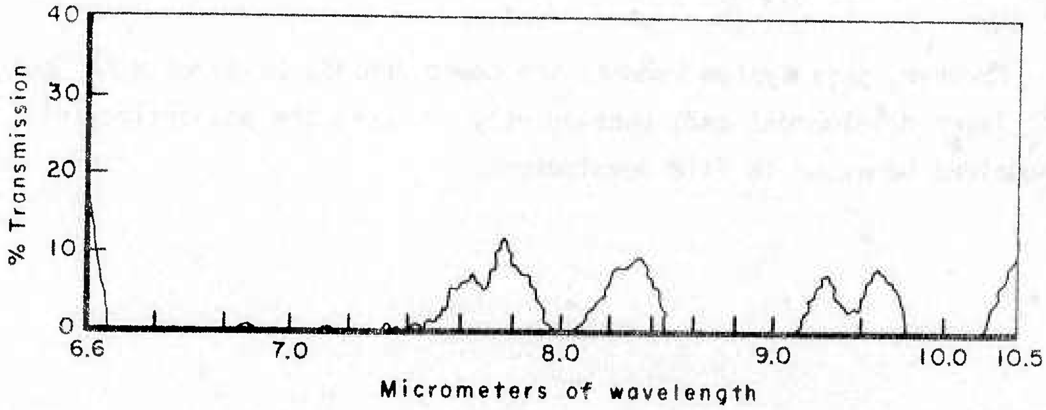

Figure 13a. A 6.6 to 10.5 μm Transmission Curve of 7969 Film Coating

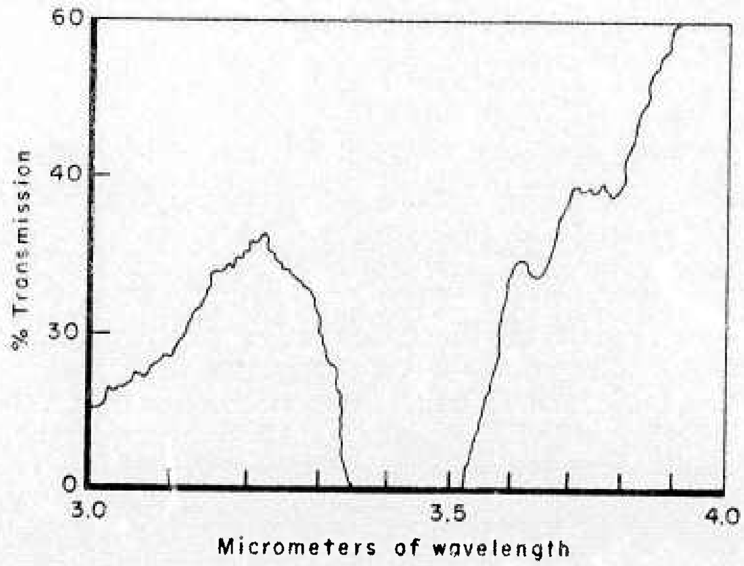

Figure 13b. A 3 to 4 μm Transmission Curve of 7969 Film Coating

Figure 14 illustrates a possible system suitable for such systems as mini-RPV reconnaissance. Such a system would place the developing and writing beams in approximately coincident positions.

Figure 15 illustrates a possible CO_2 laser line development scheme. Such a system would be suitable with ERO satellites.

Further, this system reduces the power density compared with "point" CO_2 laser development and, consequently, reduces the possibility of anomalous behavior in film development.

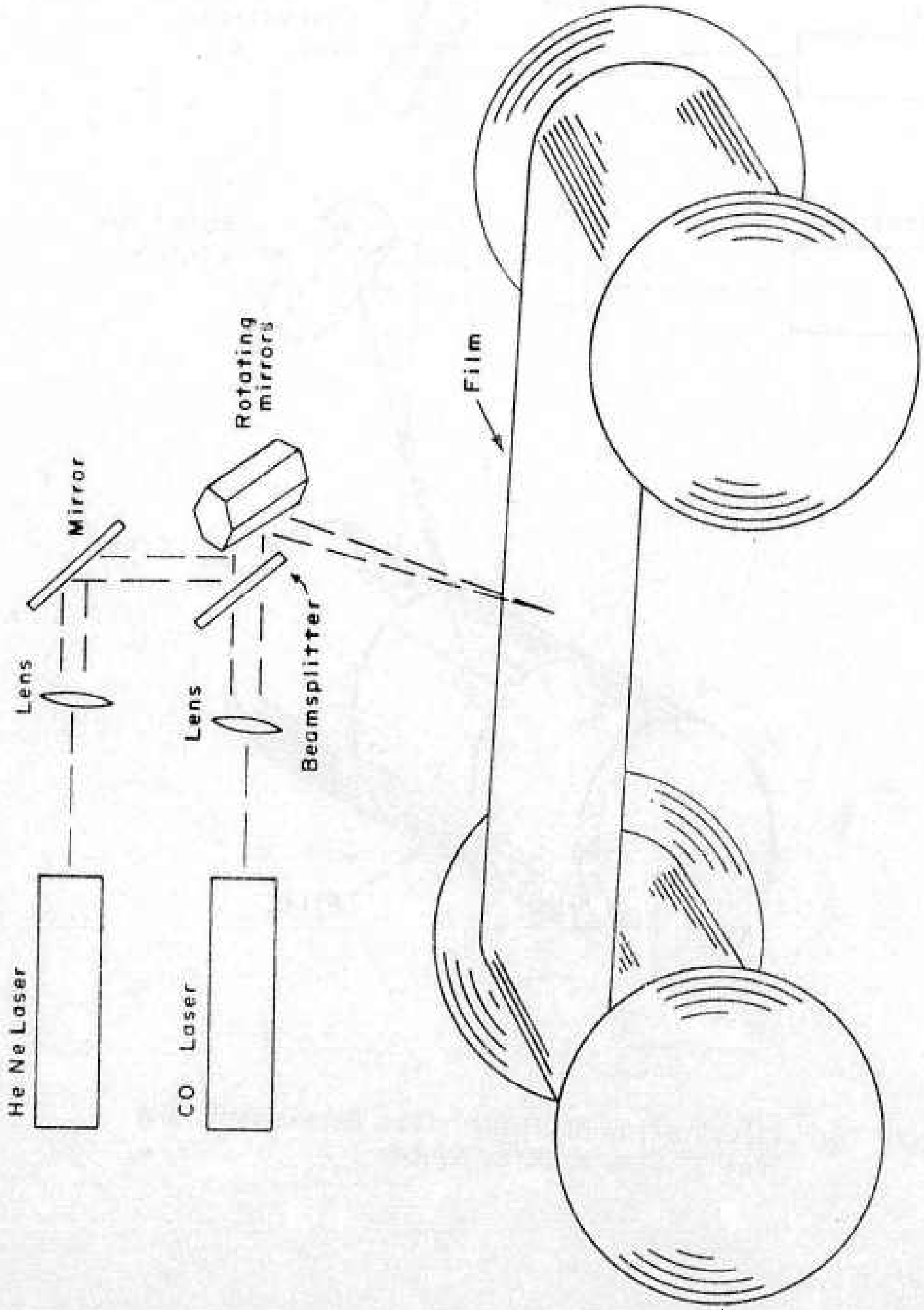

Figure 14. Illustration of "Point" Scan Writing/Development System

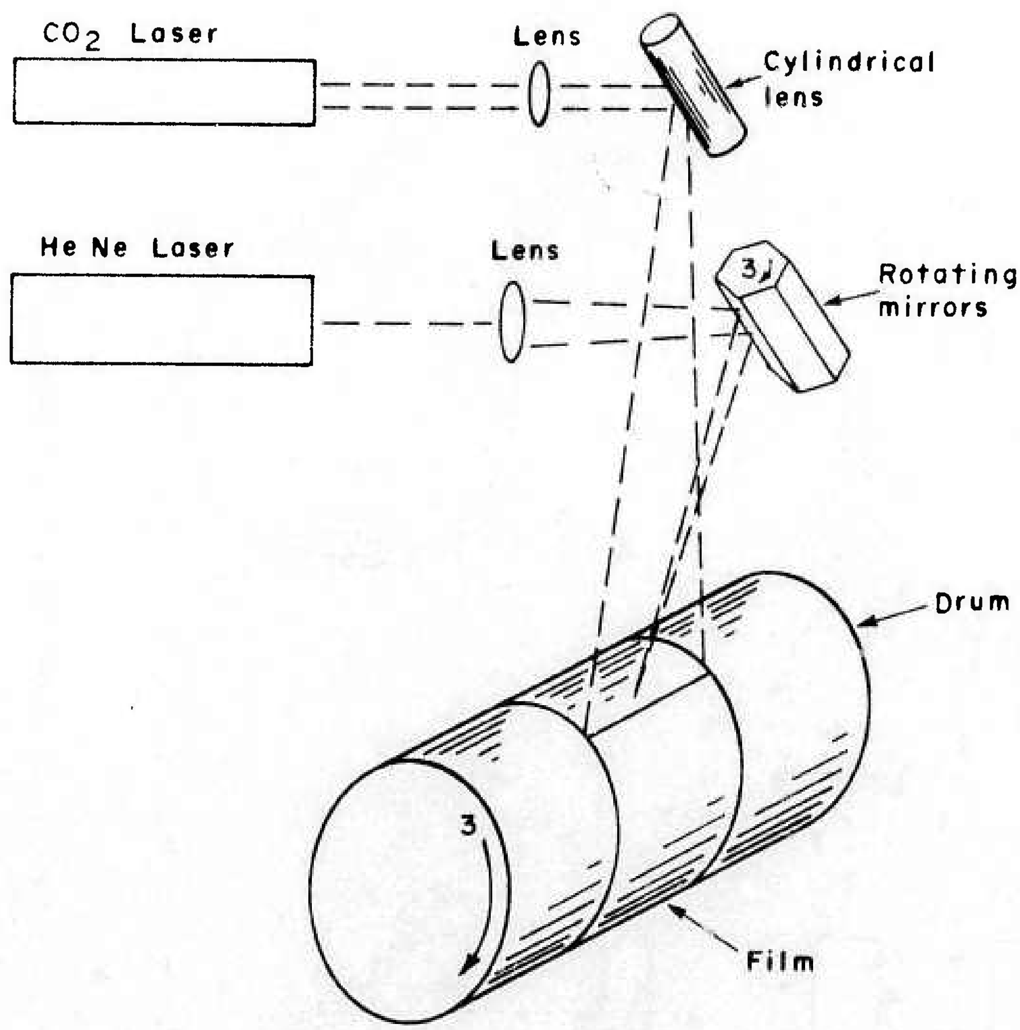

Figure 15. Illustration of "Line" Scan Development and "Point" Scan Writing System

SECTION IV

CONCLUSIONS

1. ASSESSMENT OF WORK PERFORMED

Experimental results indicate that approximately 5 joules of 10.6 micron CO_2 laser energy per cm^2 of dry silver film will develop the film in less than one second, i.e., to developed densities of approximately 1.5, for film exposed to D_{max} densities.

One possible future application of CO_2 laser development of dry silver film is a mini-RPV (model plane). Such a system, using 70 mm dry silver film with 2000 line pairs per inch resolution would require approximately an 8-watt CO_2 laser. This number is calculated as follows:

$$P = \frac{LWE}{R} \cong 8\ 1/3 \text{ watts}$$

where,

L = writing rate of mini-RPV, 200 lines/sec

W = film width, 7 cm

E = developed energy required, 5 joules/cm^2

R = film resolution on system resolution, 2000 lines/inch

An 8-watt CO_2 laser is within the power range of waveguide lasers. Consequently, the physical size of a CO_2 laser development system for dry silver film would not be extremely large.

2. RECOMMENDATIONS FOR FUTURE WORK

The experimental work performed was for static development. It is recommended for future work that a scanner be set up to determine the exact power requirements for film development.

The experimental setups suggested would appear as shown in Figures 14 and 15.

As a concluding remark, in this technical report, we have endeavored to establish a concrete platform of facts so that future work in this area such as we have suggested can progress in a logical and methodical manner.

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